CORE
Metadata, citation and similar papers at core.ac.uk
Provided by International Institute for Science, Technology and Education (IISTE): E-Journals

Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.6, No.18, 2016
www.iiste.org

# Estimating electron probe diameter in the scanning electron microscope

Mohammed Abdullah Hussein
University of Kirkuk
College of agriculture / Hawija
Dept. of mechanization and agricultural equipment

Mohanad Q. Kareem,
University of Kirkuk
College of Science
Dept. of physics

**Abstract**

The research aims to produce the theoretical study on the objective magnetic lens to estimate the electron probe diameter through the study of the parameters that effect on the efficiency of the scanning electron microscope, the optical performance of the objective lens depends used in the scanning electron microscope by ability to form precise electron probe and it focus on the specimen surface to be examined. The affective final electron probe diameter represented dp of the most important parameters that determine the resolving power in the scanning electron microscope, which in it role depends on several parameters related by focal properties of the objective lens as focal length f, Spherical Cs, chromatic Cc and diffraction dd aberration coefficients ,As it has been calculating the affective total diameter dp to the incident electron beam on the specimen surface , and the accompanying from broadening due contributions the Spherical , chromatic and diffraction aberrations which suffers from it the objective lens as a function of the angle of aperture αp to get on the smaller size of the electron probe at optimal aperture angle

**Keywords:** electron probe diameter, magnetic objective lens, magnetic lens focal properties.

## 1. Introduction

The electron optics represent is one of the branches of physics which study the behavior of the electron beam and it the mechanism of control in magnetic fields and electrostatic to get on the image of the surface objects.

This science was generated in 1897 when Joseph Thomason discovered an electron. from The most important applications the electron microscope . The develop continues in the electron microscope and a variety of uses, depending on the various fields of science. It was built electron microscopes by high resolving power , in the 1935 Knoll studied a surfaces of objects and showed defects that occur in it from through the design of scanning electron microscope with resolving power of 100 μm (McMullan, 1995) and rolled research and studies in the development of the electron microscope to get a high analysis capabilities has succeeded Van Borris and Ruska in 1939 from develop an transmission electron microscope with resolving power 10 nm, which encourage the German company Siemens to support and manufactured for the first time (Hawkes, 2004).

## 2. Theoretical details

the objective lens was Consider from the important electron microscope components which made on the concentration of the falling electron beam on the specimen surface and determines the amount of analysis of the instrument for being the only part that contributes significantly to reduce the size of Spherical Cs and chromatic Cc aberrations in the optical column which deflects of electrons strongly towards the optical axis. to minimize the spherical Cs and chromatic Cc aberrations must place The sample was near the magnetic poles of the objective lens at the peak of the magnetic field (Hawkes, 1972). Design of objective magnetic lens from type Pinhole and study the electromagnetic properties represented of distribution of the axial magnetic flux density Bz and the path of the electron beam at different acceleration Voltage as well as the path of magnetic flux lines inside the lens and the calculation of the optical properties as Spherical Cs and chromatic Cc aberration coefficients and the focal length f to get on appropriate properties of the objective lens for use it in the scanning electron microscope Figure.(1) shows design the magnetic objective lens.

 

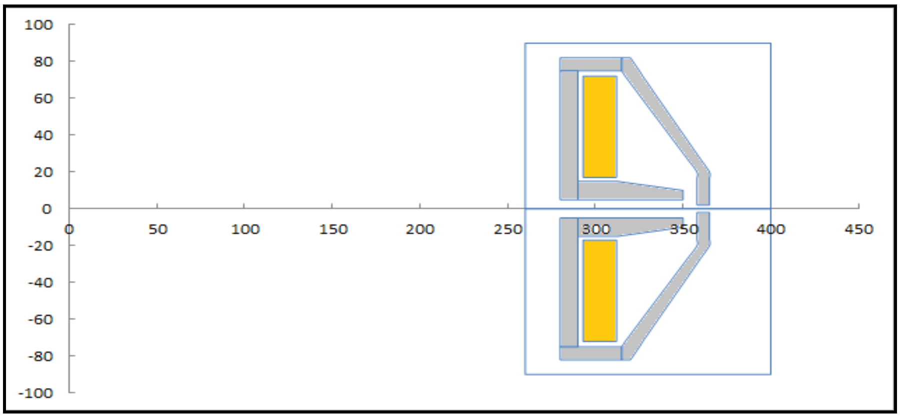


Figure .1 shows design the magnetic objective lens.

study of the distribution of the path of magnetic flux lines inside of structure the objective magnetic lens to see the optical performance of the lens using a program (Flux) developed by Munro in 1975 to draw the magnetic flux lines of electromagnetic lenses, for the great importance of these lines to study the lens behavior and know the magnetic leak that happening in its structure. The concentration of these lines in high density in reigns that have a high magnetic flux and less density or spaced from each other in the reigns that have low magnetic flux . Figure. (2)shows the path of magnetic flux lines within the objective magnetic lens structure.

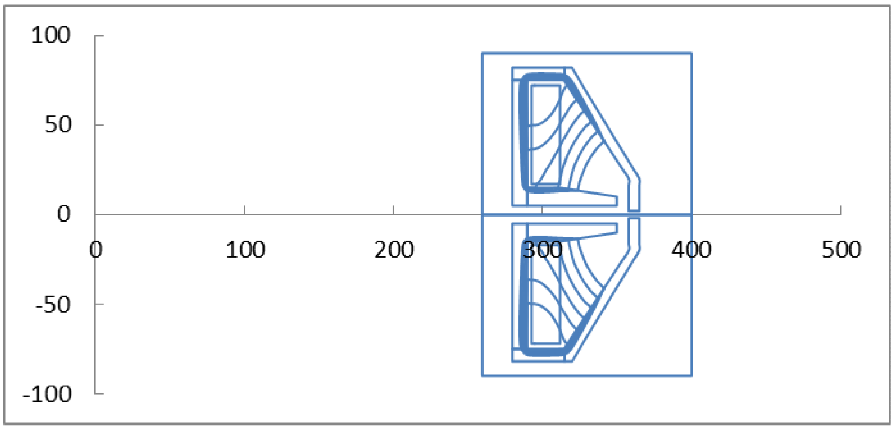


Figure .2 shows the path of magnetic flux lines within the objective magnetic lens structure.

study of the distribution of the axial magnetic flux density Bz at excitations (NI = 500, 1000) using AMAG program which is depend on the finite element method (Lencovà, 1986), as it calculates the axial magnetic flux density of the lens and giving value as well as calculates the magnetic flux density in the magnetic circuit and the lens excitation from distribution of the axial magnetic flux density. Figure. (3) shows the distribution of axial magnetic flux density Bz note from the figure that the higher value of the axial magnetic flux in the middle distance between the magnetic poles and reduce by away toward the poles. Table (1) shows the detailed results from the positions and the values of the maximum magnetic flux density Bmax at excitations (NI = 500, 1000)A.t. Through the table that excitation (NI = 1000) A.t has the highest value for Bmax, and this in its role will give a good focal properties to the lens (Mulvey, 1982).

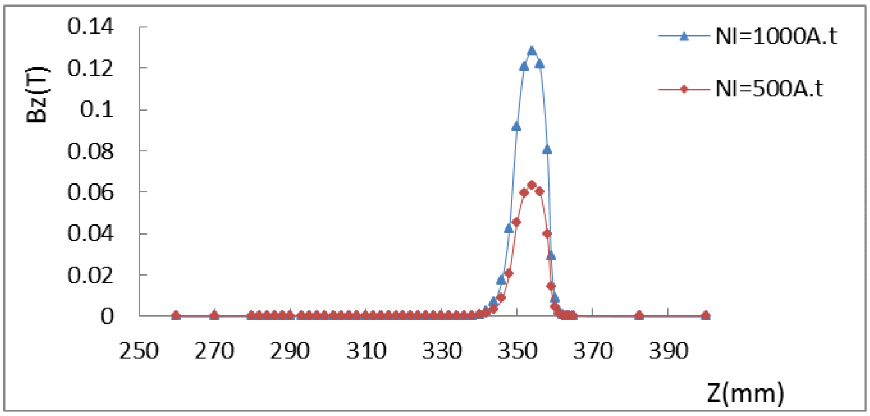


Figure .3 shows the distribution of axial magnetic flux density Bz

Table 1: shows the detailed results from the positions and the values of the maximum magnetic flux density Bmax at excitations (NI = 500, 1000)A.t

| Excitation value(A.t) | position of the maximum magnetic flux density Bmax(mm) | values of the maximum magnetic flux density Bmax(T) |
|---|---|---|
| 500 | 354 | 0.0635 |
| 1000 | 354 | 0.1283349 |

Calculating the electron beam trajectory inside the objective lens using the M21 program prepared by Munro in 1975, which is calculate the optical properties of magnetic lenses that calculate of distribution of the axial for them using program (AMAG). and operation in the zero magnification to find the refraction positions of the electron beam Zp and its intersection with the optical axis Zi at excitations (NI = 500, 1000) A.t and acceleration voltage (Vr = 10kV). Figure. (4) shows trajectory of the accelerated electron beam by voltage (Vr = 10kV)

Table (2) shows the refraction positions of the electron beam Zp and intersection with the optical axis Zi at excitations (NI = 500, 1000) A.t. Note from the two tables (1,2) that the excitation (NI = 1000) A.t has the highest value for the distribution of magnetic flux density and less focal length of the lens which gives the possibility of higher concentration and thus the proportion of aberrations less (Podbrdsky, 1986).

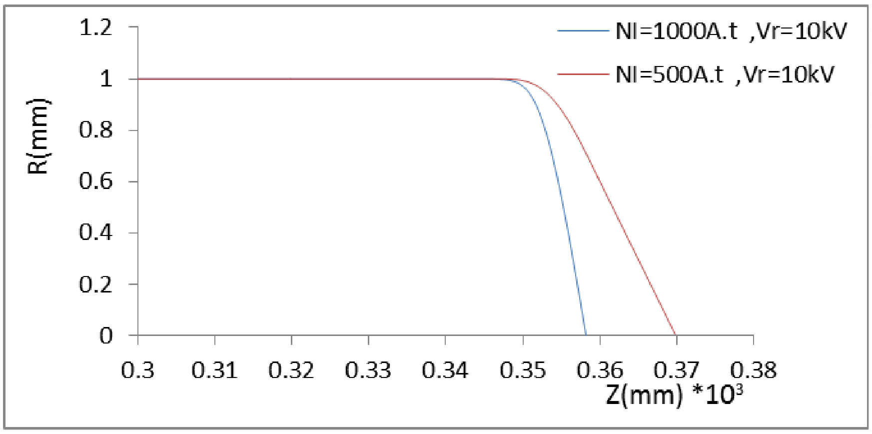


Figure .4 shows trajectory of the accelerated electron beam by voltage (Vr = 10kV)

use of M21 program to calculate the focal properties to the objective lens that represented by spherical and chromatic aberrations and focal length as a function of excitation factor NI / √Vr excitation (NI = 1000) which achieved the best results, found that the values Cs , Cc, f decrease with increase of excitation factor figure. (5) Shows The relationship between the spherical Cs, chromatic Cc aberrations and the focal length f as a function of excitation factor NI / √Vr.

Table 2: shows the refraction positions of the electron beam Zp and intersection with the optical axis Zi at excitations (NI = 500, 1000) A.t.

| Excitation value(A.t) | refraction positions of the electron beam Zp(mm) | intersection positions of the electron beam with the optical axis Zi(mm) |
|---|---|---|
| 500 | 353.43 | 369.82 |
| 1000 | 352.54 | 358.19 |

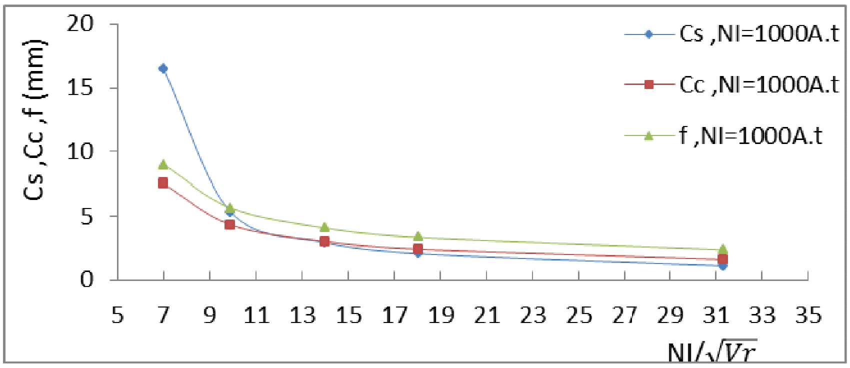


figure .5 shows The relationship between the spherical Cs, chromatic Cc aberrations and the focal length f as a function of excitation factor NI / √Vr

Calculating the times of demagnification dM in electron beam diameter by the objective lens using the program M21 and operating in the low magnification Figure. (6) shows the amount of demagnification dM as a function to excitation factor NI / √Vr, found that the times of demagnification increases with increased of excitation factor NI / √Vr, at a certain value to the incident current beam on the specimen ip, the affective real probe diameter dp be result of the geometric diameter to beam on the specimen surface dO as well as the attendant broadening due to the effects of aberrations, as spherical aberration ds , chromatic aberration dc and diffraction aberration dd , gives by the following equation: (Reimer, and Kohl, 2008).

$$d_p^2 = d_o^2 + d_s^2 + d_c^2 + d_d^2 \qquad (1)$$

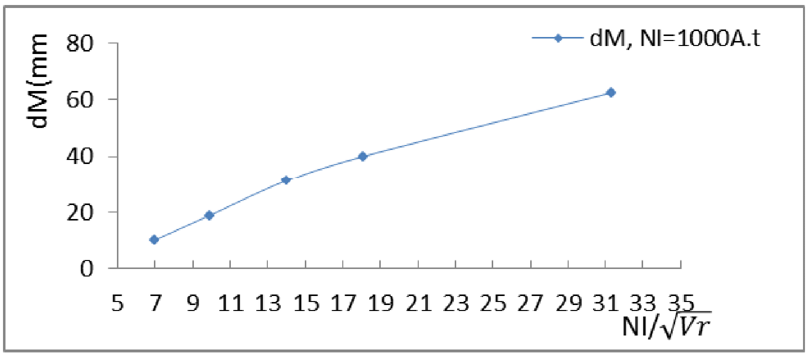


Figure .6 shows the amount of demagnification dM as a function to excitation factor NI / √Vr.

Study the effect of the aperture angle to the objective lens on the electron probe diameter by contribution the Spherical Cs , chromatic Cc and diffraction dd aberrations according to the following relationship:

$$d_p^2 = (C_o^2 + (0.61\lambda)^2)\alpha_p^{-2} + \frac{1}{4}C_s^2\alpha_p^6 + C_c^2\left(\frac{\Delta E}{E}\right)^2\alpha_p^2 \qquad (2)$$

Figure.(7) shows the relationship between the electron probe diameter and objective lens aberrations as a function to the aperture angle αp at excitation (NI = 1000) At and different acceleration voltages (Vr = 1000 - 10000) Volt, we note from the figure that the Spherical aberration Cs, chromatic Cc aberration least when reducing the aperture angle αp while increasing aberration diffraction dd.

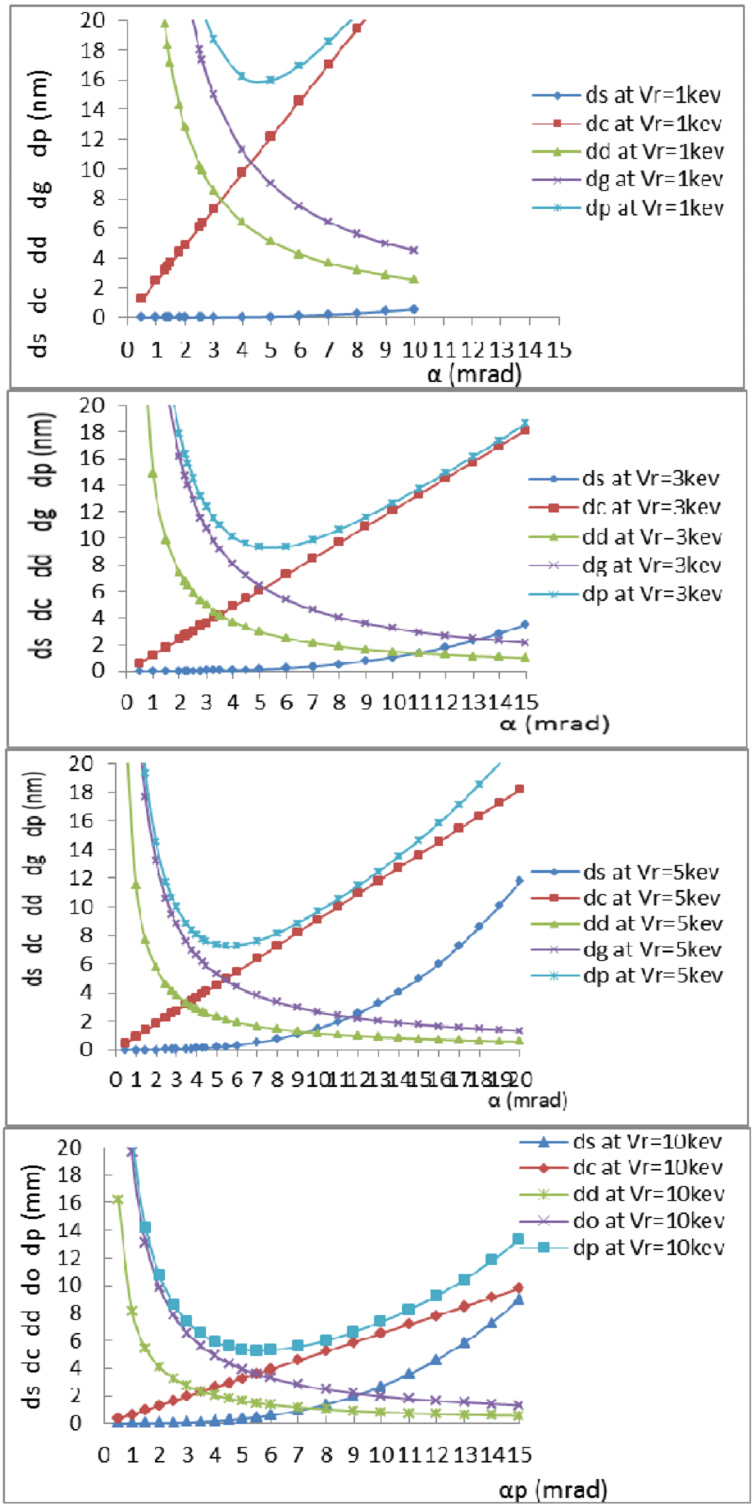


Figure .7 shows the relationship between the electron probe diameter and objective lens aberrations as a function to the aperture angle αp at excitation (NI = 1000) At and different acceleration voltages (Vr = 1000 - 10000) Volt

Table (3) shows the values of the aperture angle $\alpha_{opt}$ corresponding to the minimum diameter of the electron probe $dp_{min}$ at different acceleration Voltages (Vr=1000, 3000, 5000, 10000)Volt and excitation (NI=1000)A.t .

Table 3: shows the values of the aperture angle $\alpha_{opt}$ corresponding to the minimum diameter of the electron probe $dp_{min}$ at different acceleration Voltages

| acceleration Voltages | aperture angle $\alpha_{opt}$(mrad) | less diameter of the electron probe $dp_{min}$ (nm) |
|---|---|---|
| 1000 | 5 | 15.97245 |
| 3000 | 5 | 9.3257 |
| 5000 | 5.5 | 7.249082 |
| 10000 | 5.5 | 5.283811 |

## 3. Conclusions

By studying the focal properties to the objective lens show that spherical and chromatic aberrations decreased by increase excitation factor of the lens, which works to decrease the amount of current arrived to specimen for this reason cannot continue to increase excitation factor because of lower value to incident beam current on a specimen surface that can be obtained through it on the signal and not the noise from the specimen surface is ip = 1 pA (Bronsgeest et al,, 2008). Also, the amount of demagnification in electron beam diameter decreases by increase the excitation factor, which in role works to increase the centration of an electron beam and reduce the focal length, either for electron probe diameter and the amount of aberrations there is A perfect aperture angle proved the lower values for electron probe diameter and aberrations.

## References

McMullan, D. (1995). Scanning Electron Microscopy 1928 -1965.Scanning Vol.17,PP175-185 FAMS, Inc.

Hawkes, P.(2004). Recent advances in electron Optics and electron microscopy . Annales de la Fondation Louis de Broglie, Vol. 29, No. 1, pp.837-855 .

Hawkes, P. W.(1972).Electron Optics and Electron Microscopy. Taylor and Francis Ltd., London .

Lencovà, B. (1986).Program AMAG for computation of vector potential in rotationally symmetric magnetic electron lenses by FEM. Inst. Sci. Instrum., Czech. Acad. Sci., Brno, Czechoslovakia, pp.1-58.

Mulvey, T. (1982).Unconventional lens design. in Magnetic Electron Lenses, P. W. Hawkes, Ed., Springer-Verlag,Berlin, pp. 359-420.

Podbrdsky, J. (1986) .High current density magnetic electron lenses in modern electron microscopes. Journal of scanning electron microscopy, Vol. 3 , pp. 887-896 .

Reimer, L., & Kohl, H. (2008) .Transmission Electron Microscopy: Physics of Image Formation . 5th edition Springer Science +Business Media, LLC.

Bronsgeest, M. S., Barth, J. E., Swanson, L. W. & Kruit, P. (2008) .Probe current, Probe size, and the Practical brightness for Probe forming system . J. Vac. Sci. Technol. B Vol. 26, No. 3, pp. 949-955.